Use of Classroom Presenter in Engineering Courses

Richard Anderson[1], Ruth Anderson[2], Luke McDowell[3], and Beth Simon[4]

Abstract - **Instructors of computer science, engineering, and technology courses often teach using prepared slides displayed with a computer and data projector. While this approach has advantages, disadvantages can be severe -- including limited flexibility in delivery of material, which hinders instructors' spontaneous adaptation to students. This paper describes Classroom Presenter, a Tablet PC-based presentation system that (1) allows instructors to regain flexibility in presentation using Tablet PC-supported digital inking in an application specifically designed for lecturing use, (2) supports role-specific views and interaction mechanisms in class, and (3) introduces novel affordances including the use of wireless technology and student devices to support active learning in the classroom. As of spring 2005, Classroom Presenter has been used in over 200 courses at more than 13 institutions. Here we take advantage of our large use-base to discuss Classroom Presenter's impact on student learning and summarize best practices for lecturing with this technology.**

Index Terms - Classroom Presentation, Digital Ink, Pedagogy, Tablet PC

INTRODUCTION

For classroom lecturing, a variety of computer-based and manual classroom presentation systems are currently available, each having advantages and disadvantages. Among computer-based systems, the most common is projecting slides using a data projector. Advantages of such systems include the ability to structure material in advance, prepare high quality examples and illustrations, and easily share and reuse material [5]. Engineering instructors especially benefit from the ability to switch conveniently between slides and web content or other computer-based tools such as simulations or a programming environment. Computer-based systems are also well-suited for archiving and transmitting presentations, e.g., for distance courses. However, these advantages come at the cost of decreased flexibility during presentation – especially in the capacity to adjust the lecture based on audience reaction.

Unlike computer-based presentation systems, many manual systems (including overhead projectors and document cameras) support high quality handwriting over slides, enabling the instructor to augment prepared materials with supplemental text or diagramming. These affordances are particularly useful in engineering, where diagramming appears in many types of instruction: from sketching a force diagram in mechanics to annotating a circuit diagram in digital design.

We have developed and deployed Classroom Presenter, a presentation system that combines the advantages of existing computer-based systems with the handwriting flexibility of manual systems. Running on a Tablet PC, a pen-based mobile computer, Presenter allows the instructor to handwrite over computer-projected slides. The slides and "digital ink" are then broadcast to other machines for students' use or to drive a public display. Our software is available free for educational and research use and can be downloaded from the web [8].

The system is being used in an increasing number of disciplines at a range of institutions. It has been deployed in well over 200 courses in computer science, electrical engineering, and other science and engineering disciplines since spring 2002. Overall students and instructors have responded very positively. 55% of students felt that use of Presenter positively impacted their understanding of lecture material (only 9% indicated a negative impact (n=477)), and 69% of students would encourage other faculty to use the system (only 8% would discourage use (n=447)). For more results see [1].

The Classroom Presenter system has been used to support both traditional lectures and interactive lectures where students are making contributions from mobile computers. We have reported on use with student devices in previous work [12, 13], and will concentrate on the use of Classroom Presenter for traditional lecture presentation in this paper. We believe that the fundamental contribution of Classroom Presenter and related systems is the flexibility provided to instructors by enabling a smooth integration of handwriting via digital ink and electronic slides. We begin by giving a brief description of the presentation system and identifying some of its key features. We then discuss how instructors have used digital ink and identify some best practices in using this technology. Many of the lessons on how best to use Classroom Presenter apply equally well to other presentation systems supporting digital ink. Additional information on how Presenter has been used in the classroom, and student and instructor reactions to the system can be found in [1].

RELATED WORK

There has been a history of work in developing technologies to support the delivery of presentations. The two key components of Presenter are the integration of slides and

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writing and the separation between the instructor's machine (for instructor use) and the display machine (for student viewing). An early system that integrated slides along with student and instructor writing was Lecturer's Assistant [7]. Another notable system which supported writing on slides was ZenPad [6], the presentation component of the Classroom 2000 system. Golub [9] has independently developed a system for presenting material from a Tablet PC. LiveNotes [11] is another Tablet PC based system which has similar functionality to Classroom Presenter, including distributed ink across multiple machines, and support for electronic slides. LiveNotes is geared more towards distributed note taking than instructor presentation. The DyKnow system [4] has goals similar to our own. In DyKnow, students sit at PCs, optionally equipped with pen enabled technology, while the instructor lectures from an electronic whiteboard, video tablet or PC. Recent versions of PowerPoint enable some ink functionality, and some instructors use other applications such as Windows Journal or OneNote to combine writing and slides from the Tablet PC. Our extensive experience with Classroom Presenter over a wide range of courses and instructors allows us to offer guidelines for use that apply to Classroom Presenter as well as other ink-based presentation systems such as those described above.

SYSTEM DESCRIPTION

Presenter is a slide-based presentation system. In its basic deployment, the instructor runs Presenter on a Tablet PC and writes on the slides. Figure 1 shows a screenshot from the instructor machine, showing the slide area for writing digital ink, a film strip for navigation, and pen and navigation controls. A second view, shown in Figure 2 is shown from the data projector. This shows just the slide and the digital ink. The second view can either be from VGA output on the Tablet PC or from a second machine which is wirelessly connected to the presenter machine. The application also has a student view, shown in Figure 3, for use by a viewer who is connected to the presentation by a personal machine. The student view has inking controls and shows the current slide, and optionally the previous slide. Student inking is provided to allow personal note taking, as well as student annotation of slides which are sent back to the instructor [12, 13]. In the default mode, the student slides are synchronized with the instructor's machine, but there is an option that allows the student to unlink and navigate the slide deck independently.

I. Tablet PC based Presentation for Lecture

A key part of our system is the use of the Tablet PC as the instructor device. Tablet PCs enable integration of digital ink with slides, allowing annotation with natural handwriting. Presenter was designed specifically with instructors in mind, incorporating navigation facilities such as a film strip (left side in Figure 1) for previewing and viewing slides out of order, an unlimited amount of whiteboard space, simple ink color controls, as well as a slide shrink feature to allow additional discussion space on a full slide.
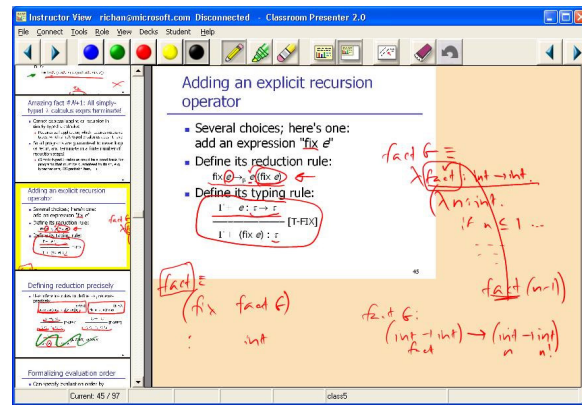

FIGURE 1
INSTRUCTOR VIEW WITH NAVIGATION AND PEN CONTROLS. THE SLIDE SIZE HAS BEEN REDUCED TO PROVIDE THE INSTRUCTOR WITH EXTRA ANNOTATION AREA. FIGURES 1, 2 AND 3 ARE FROM A MASTER'S LEVEL PROGRAMMING LANGUAGE CLASS.
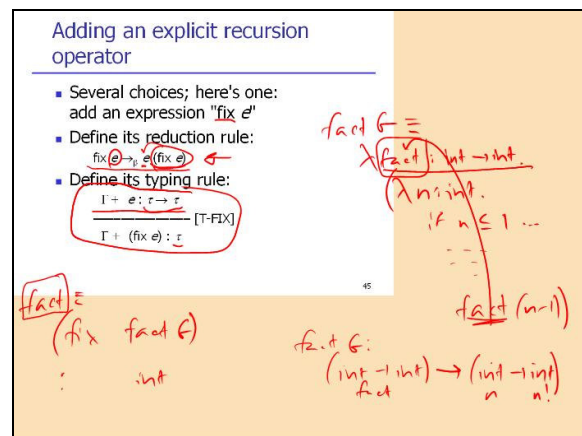

FIGURE 2
PROJECTOR VIEW SHOWING ONLY THE SLIDE. THE PROJECTOR VIEW IS SYNCHRONIZED WITH FIGURE 1'S INSTRUCTOR VIEW.
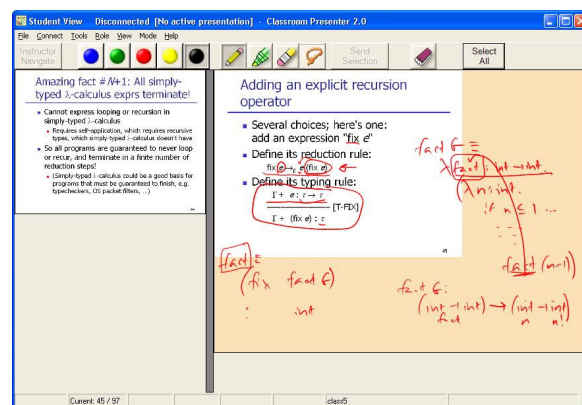

FIGURE 3
STUDENT VIEW SHOWING THE SLIDE ON THE RIGHT AND THE PREVIOUS SLIDE ON THE LEFT.

II. Distributed Application

The application is distributed and machines keep their data in sync through networked (wired or wireless) communication. As a distributed application it is a natural fit for distance learning deployments (which, in fact, was one of the initial use scenarios [3]). Another advantage of the distributed, wireless

model is untethering the instructor from the data projector, giving the instructor freedom to move about the classroom. One of the first users of the system regularly took the tablet into the audience, TV talk show style, so that students could write their contributions to the slides.

An important advantage of a distributed system for presentation is that it allows different participants to have different views. The instructor view devotes space to controls, previews of upcoming slides, and basic elements of the Windows display like a clock. The public display dedicates all of its space to the current slide. The student view, shown in Figure 3, is similarly tailored, for example, showing both the current and previous slide to encourage "late-breaking" questions as the instructor moves through the lecture.

III. Instructor Notes

Presenter's separation of views also affords the creation of private instructor notes, which can be used to support a more interactive lecture. Instructors' private objects automatically appear in the instructor view but not in the student or projector views. (Both views display the same class-time ink.) Figure 4(a) shows examples of instructor notes as used in a computer architecture course while Figure 4(b) shows the projector view of the slide after it has been discussed. Instructor notes might, e.g., remind instructors of complex
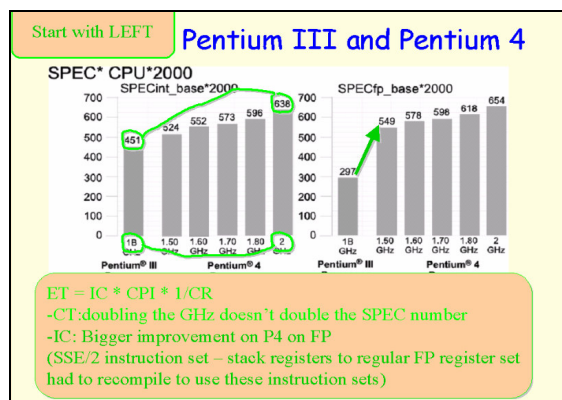

FIGURE 4(A)
INSTRUCTOR VIEW BEFORE DISCUSSION. INSTRUCTOR NOTES INCLUDE THE TWO ROUNDED TEXT BOXES AND THE TWO LINES AND AN ARROW.

FIGURE 4(B)
PROJECTOR VIEW AFTER DISCUSSION. INSTRUCTOR HAS DRAWN OVER GRAPHS DURING DISCUSSION AND RECORDED INFORMATION RELEVANT TO THE GRAPHS. NOTE THAT THE INSTRUCTOR OBJECTS ARE NOT DISPLAYED (ALTHOUGH THE INSTRUCTOR HAS DRAWN SOME OF THEM IN).

facts and equations, scaffold an instructor's discussion of a slide, remind the instructor of discussion topics to raise in class, or fill in "holes" that the instructor has left in the public view of the slides to encourage student note-taking.

IV. Integration with Student Devices

Presenter was designed so that it could be integrated with student devices in the classroom. This integration includes the ability of students to provide real-time, anonymous feedback on slides to the instructor [2]. In addition, when students (or groups of students) are equipped with tablet computers, the instructor can periodically ask them to solve a problem or respond to a question. Students write their solutions on the tablet and submit them wirelessly to the instructor, who can display one or more to the class, annotating the responses with ink as they are shown. Student responses can be saved for review after lecture by the instructor or made available electronically to the students [12]. Support for non-tablet student devices is also available [13].

BEST PRACTICES IN INK-BASED LECTURING

Instructors have many different styles of writing while lecturing and different types of writing are used to support different pedagogical practices. The amount of writing varies between instructors, and also by subject. Examples of common inking practices include:

- Attentional marks for emphasizing slide content (Figure 2)
- Short phrases written for emphasis (Figure 4B)
- Spontaneous written examples (Figure 2)
- Diagrams used for explanation (Figure 5)
- Annotation of diagrams on slides (Figure 4B)
- Planned activities such as writing lists or filling in tables (Figure 6)

In reflecting on our own teaching, and in observing other instructors we have seen that sometimes ink usage is very effective at tying speech to slide content, and introducing new material, while at other times it is distracting and confusing. We have attempted to collect our observations in a list of best practices for using digital ink. Although writing on slides is perfectly natural and requires no training, it is possible to do it badly, and care is necessary to present material in the most effective manner to students. While our observations and advice apply most directly to the use of the Classroom Presenter system, many of our findings are highly relevant to users of other digital ink-based systems.

We have collected student and instructor surveys from over 30 courses across three institutions and a large number of other course artifacts including emails from instructors and slide decks with ink from many other courses. For eight courses we have full digital archives (over 240 hours total) of the entire course including ink, slides, audio, video and student interactions for each class meeting. These archives in particular have proved invaluable and we have spent many hours reviewing and replaying them to make detailed observations of digital ink usage in the classroom. Courses we have observed either in person or on digital archive span a
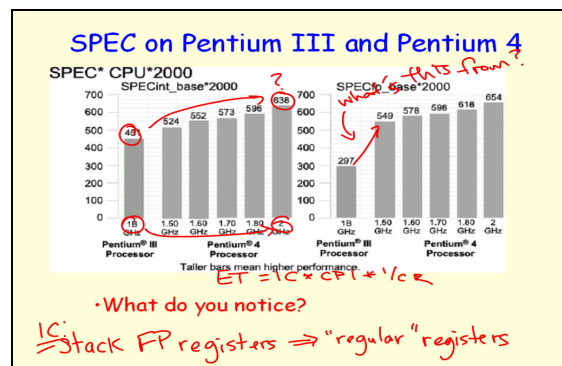
wide range of topics from introductory courses in programming and data structures to more advanced topics such as compilers, artificial intelligence, programming languages, and human-computer interaction. In addition to data we have collected from other instructors, among the authors we have taught a total of 22 courses and given numerous presentations using a digital ink based system.

FOCUS ON CLARITY

Using digital ink in lecture opens up new possibilities in terms of both expressiveness and flexibility in presentation. However, using this new power effectively requires attention to a number of details to ensure that the presentation is fully comprehensible. In this section we describe several of the most critical factors we have observed in use of these systems.

I. Legibility

Information must be legible in order for students to gain anything from it. The obvious advice is to write as neatly as possible, although the excitement of teaching and the goal of concentrating on the audience can make this hard to do. Understanding some of the specific challenges of writing on a Tablet PC can help improve legibility. There is variation between Tablet PCs, so if there is an opportunity to choose between models, it is advisable to determine which supports the easiest writing. Differences between Tablet PCs include the size of the screen, the feel of the pen, the slipperiness of the screen, and the viewable angle.

Screen real estate is an important issue. The writing area on a Tablet PC is less than on a classroom sized whiteboard, which limits the size of things that can be written and the amount of material that can be left up for students. The writing size is generally limited by the size of the instructor's handwriting, not by the number of pixels, so a Tablet PC with a larger physical screen might be preferable to a smaller screen - even if they have the same number of pixels.

Instructors must plan their writing in order to avoid running out of space. It is not unusual to run into a margin when writing - perhaps because writing on a Tablet PC tends to come out larger than writing on paper. The recursion example in Figure 7, created by an experienced user, has some of the writing running into the margin. The example could easily have been started further to the left to avoid the problem.

II. Color usage

The choice of ink color should be made primarily for contrast, either with the slide background or with other ink. It is desirable to have the ink color contrast with the slide text color as well, in order to make it easy to identify ink annotation. For example, if the slides are black text on a white background, blue or red might be good ink colors. A blue background with white text and yellow ink can also be effective.

Special care needs to be taken to make sure that colors contrast with the slide background. We have observed many instances when the slide background changes (say from blue

to white), and the instructor continues to use the same ink color which is almost invisible on the new background. (Students may not notice the new ink, and thus say nothing).

Choosing colors for contrast can be tricky. Note that the same RGB colors can appear very different on different devices and viewing situations. For example, different viewing angles of a LCD can make green look black. Also, we have seen colors which were very easy to see on a Tablet PC, but almost vanished when displayed with a data projector.

III. Clutter

A number of problems emerge when ink is cluttered. First, when ink is overdrawn, the new ink is not distinct from the old. The Tablet PC ink is solid, so multiple strokes of the same color merge. Common patterns have been observed where an instructor will make multiple underlines close together (e.g., underlining both terms and variables) but the separate marks are not visible to the viewers. Another problem with clutter is that it can become difficult to find the new ink as a viewer. This is especially the case when the marks are made in areas that already have writing.

An additional cause of clutter is when one slide is used to convey many different points. For instance, in one lecture the same basic diagram of diamond inheritance in a programming language shown in Figure 5(a) was used to illustrate nine distinct points, leading to the confused state of Figure 5(b).
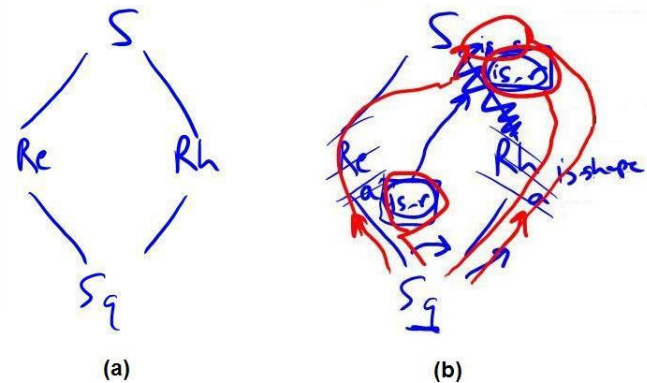

FIGURE 5
(A) IS A BASE DIAGRAM USED IN A DISCUSSION OF MULTIPLE INHERITANCE IN A PROGRAMMING LANGUAGE. (B) SHOWS THE RESULT AFTER MANY DIFFERENT POINTS HAD BEEN ILLUSTRATED ON THE SAME DIAGRAM.

One solution to the clutter problem is a periodic cleanup of the slide. Many instructors will erase all the ink on the slide when it starts to be cluttered. For instance, we observed one instructor who cleaned a slide up to ten times during one discussion. This technique can be effective, as long as there is no ink on the slide that needs to be saved. This does not work if there has been a diagram created with ink, such as the one in Figure 5(b), and the instructor only wants to remove attentional ink such as underlines and circles. However, Presenter enables instructors to selectively erase ink strokes by using a special button (supported by some Tablet PCs) on the eraser end of the pen, or by clicking on a software button to switch the pen tip to eraser mode.

Changing colors can be also used to mitigate the effects of clutter, allowing new attentional marks to be distinct from older ones. However, after the second color is introduced, we have observed that additional colors do not add much benefit.

IV. Pacing

One advantage of writing is that it leads to displaying material at a rate that is comprehensible for students, both for listening and for note-taking. This advantage is often stressed by blackboard style instructors. It is important that writing remain visible long enough for students to comprehend the ink. A common mistake we have observed is for instructors to change or erase the slide immediately after writing has been completed. Instructors accustomed to switching quickly between slides projected from their computer may need to make a conscious effort to pause before advancing slides or erasing – unlike chalk, digital ink is erased both immediately and completely.

PLAN FOR INK USE

While Presenter can be used with slides that were originally designed for other presentation mediums, such use does not take best advantage of Presenter's capability for the introduction and dynamic modification of content. This section describes several issues related to designing slides specifically to support ink use in lecture. Figure 6 shows examples of several slides designed for this purpose.
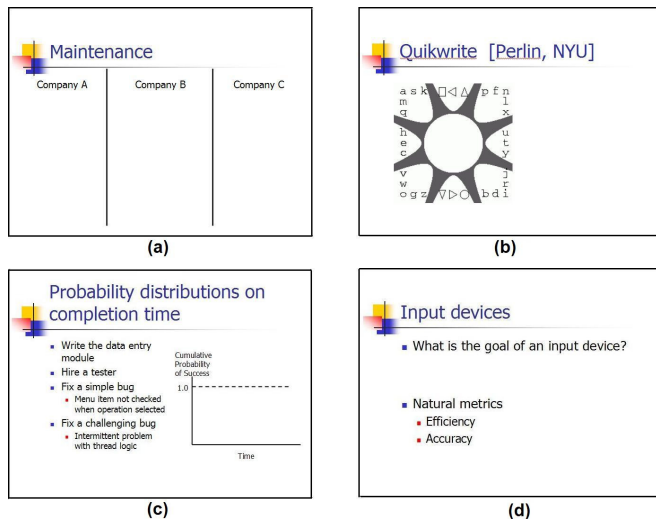
FIGURE 6
SLIDES DESIGNED FOR INK USE: (A) COLLECTIVE BRAINSTORM (B) TEMPLATE FOR DEMONSTRATING A WRITING SYSTEM (C) GRAPH DRAWING (D) SPACE TO ANSWER QUESTION

One key design issue is leaving adequate blank space on the slides for inking. We have observed many examples where an instructor wanted to add a diagram to a slide, but the small amount of space available resulted in a diagram that was very cramped and hard to understand. Instructors need to anticipate where inked diagrams will be useful, then allow ample space for such inking along with any accompanying attentional marks or clarifications. In addition, pre-created

diagrams need to be large enough to enable the instructor to easily write inside of them. Presenter's built-in slide shrink (demonstrated in Figure 1) and whiteboard features help alleviate some of these issues.

A second aspect of leaving space relates to allowing adequate room for student note-taking. When student devices are not present, instructors with prepared slides will frequently distribute handouts with small versions of each slide for such note-taking. Typically, students can write smaller on such handouts than an instructor can write with digital ink, so recording basic inking is not a problem for students. However, the instructor has the advantages of being able to re-use slide space by erasing and of being able to use contrasting colors. These options may not be available to most students on paper. To ensure that students have adequate space for note-taking, it may be necessary to split material across multiple slides or to leave adjacent slides blank.

Regarding note-taking, we have also observed several instructors who intentionally omit key words, phrases, or results from their slides in order to fill in the "answers" for these quantities during lecture (see Figure 6d). When paired with handouts of the slides, this approach is consistent with the philosophy of using "guided notes" [10] and has been shown to lead to improved student recall [5]. This practice enables instructors to solicit these answers through classroom discussion as time permits, and helps to ensure that students remain attentive during lecture (writing down such answers) even when slide handouts have been provided. Presenter's instructor notes feature is an excellent way for instructors to remind themselves of the precise phrasings and results that they wish to use for such answers.

Instructors can also design slides to foster other kinds of discussion (or to remind them to start such discussion). For instance, a slide might include a blank pair of axes for discussing and graphing some quantity (Figure 6c), or several blank columns for brainstorming/comparing different approaches (Figure 6a). Alternatively, instructors might use a standard symbol (such as a picture of a brain or a question mark) to indicate points where discussion would be helpful. Such prompts also serve to remind the instructor not to focus only on the technology but to foster classroom interaction.

USE INK TO CONVEY MEANING

One important use of ink is to make connections between speech and content. Ink can draw focus to the current formula and diagram, and can significantly aid comprehension. In addition, such ink can be used to resolve deixis in speech (e.g., circling the variable x, when saying "this variable").

There are also many opportunities for ink use that not only draws attention but also adds extra meaning to the slide. For instance, we have frequently observed that lecturers will make a brief ink jot next to each item in a bulleted list that they are discussing, but some go further. For example, one instructor added sequential numbers next to each point in a list as it was discussed, in order to emphasize the multiple types of items. Other such informational markings we have seen include the use of exclamation marks to emphasize the

importance of a point, and the use of pluses and minuses to note the relative merits of different points.

On the negative side, we have also observed situations where purely attentional marks bewilder the audience by unintentionally conveying additional meaning. For instance, if a horizontal dash sometimes conveys "negative" and sometimes is just an attention jot, students may be confused. Likewise, instructors need to be careful that arrows and attentional markings are not mistaken for letters or numbers. Such pitfalls can be avoided partially by careful slide design and partially by periodic reflection during lecture.

Ink can also convey meaning not only with its shape, but also with its color. We've previously discussed the importance of ink having good contrast with other displayed material, and a change of colors can be used to emphasize different points. In addition, instructors sometimes use different colors to represent different kinds of information or activity. For instance, Figure 7 shows an example where an instructor diagrammed unrolling of a recursive function call by drawing a different state box for each function call, then used a different color to separate activities that occurred as the recursion deepened and as it unwound. (Figure 7 was originally in color, but in a printed copy may not convey full information.)
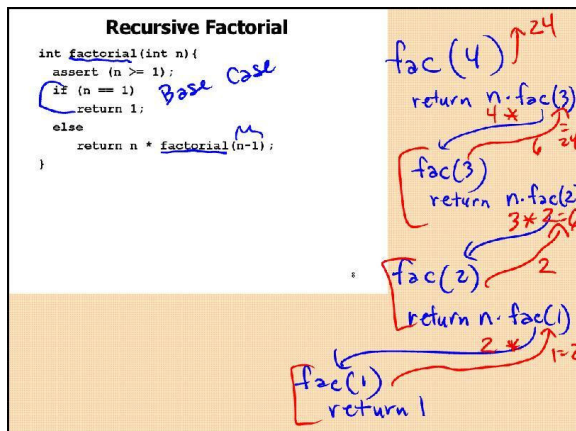

FIGURE 7
COLOR USED TO DISTINGUISH BETWEEN DIFFERENT PHASES IN RECURSION.

ENGAGE THE AUDIENCE

A risk inherent in using new technology in the classroom is that the technology becomes a distraction rather than a complement. In particular, when delivering a lecture from a pen based computer there is a temptation to look at the computer instead of the audience. The problem is not specific to this technology – it is common to see instructors talking to the blackboard or to PowerPoint slides on the laptop. However, we have observed this as a common issue in lecturing from the Tablet PC, and the form factor of the device exacerbates the problem. If the Tablet is lying flat, the viewing angle is much greater than for a laptop, so the eye gaze problem can be worse. Direct manipulation of the screen

also can contribute to the instructor not looking at the audience. The best practice is to conscientiously look at the audience, and be aware of the risk of focusing on the Tablet. Another action that can help is to periodically move away from the Tablet. Some instructors use a style where lecturing from the Tablet is intermixed with pointing at the screen.

CONCLUSION

Good teaching is not about technology; it is about interacting with and conveying information to an audience. In this paper we have described Classroom Presenter and how it enables instructors to bring back more interaction and flexibility into the classroom. In addition, we have described a number of best practices for the use of Classroom Presenter and similar systems. We hope that these guidelines will help beginning users avoid the most common pitfalls and alert them to the new pedagogical possibilities.

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